Original Article

Effects of long-term use of the lower lingual arch from 8.5 years to 13.2 years

Matthew W. Joosse[a]; James Mungcal[b]; Roger Boero[c]; David Chambers[d]; Heesoo Oh[e]

ABSTRACT

Objectives: To investigate the effects of long-term use of the lower lingual arch (LLA) on the sagittal and vertical positions of the permanent lower incisors and first molars.

Materials and Methods: The sample consisted of 98 patients who were treated with an LLA (LLA group) and 39 patients who were treated without an LLA (no-LLA group). The positional changes of the lower incisors and first molars were analyzed after performing mandibular structural superimpositions on lateral cephalometric radiographs taken before treatment (T1) and at the end of LLA therapy (T2). The mean ages at T1 and T2 were 8.5 years and 13.2 years, respectively. Study casts were analyzed to quantify arch dimensional changes.

Results: Mesial movement of the lower molar cusp was similar between the LLA and no-LLA groups, but the vertical position was slightly greater at T2 in the LLA group. In the LLA group, there was a molar tip-back effect, and the lower incisors were proclined 4.2° more than in the no-LLA group. Arch perimeter decreased 3.6 $\pm$ 2.6 mm without an LLA and 0.97 $\pm$ 3.7 mm with an LLA. Intercanine and intermolar widths both increased about 1 mm more with an LLA ($P < .0001$).

Conclusions: The LLA does not seem to restrict mesial movement and vertical eruption of the lower incisors and molars in the long term. The LLA effectively preserves the arch perimeter at the expense of a slight lower incisor proclination. (*Angle Orthod.* 2022;92:189–196.)

KEY WORDS: Lower lingual arch; Long-term; Leeway space; Vertical control; Incisor proclination; Arch perimeter

INTRODUCTION

The lower lingual arch (LLA) is an effective and conservative treatment modality to resolve mild to moderate lower incisor crowding in the mixed dentition. It maintains the lower arch perimeter by preserving leeway space. Previous literature has shown that leeway space is not normally involved in the resolution of incisor crowding in untreated dentitions.[1–3] With LLA therapy alone, Brennan and Gianelly[4] reported an average of 4.85 mm resolution of crowding in 60% of the treatment population. DeBaets and Chiarini[5] showed incisor crowding resolution in 70% of patients with mixed dentition. Dugoni et al.[6] revealed an LLA reduced incisor irregularity from an average of 7.81 mm to 1.04 mm and showed stability in a treatment group that did not require phase 2 treatment.

Although the effects of an LLA in preserving arch perimeter by preventing mesial movement of the lower first molars have been well documented,[4–10] the vertical control effects on the lower incisors and molars have shown conflicting results.[7,8,10,11] Singer[8] and Villalobos et al.[10] reported a positive effect on vertical control of the lower molars, but Rebellato et al.[7] and Odom[11] reported no effects. Some clinicians advocated using an LLA for vertical control of lower molar eruption in growing patients, but there is a lack of consensus as to whether doing so is effective.[12] In addition, most LLA

[a] Private Practice, Williamsburg, Va, USA
[b] Private Practice, Sacramento, Calif, USA
[c] Associate Professor, Department of Orthodontics, Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, Calif, USA
[d] Professor, Department of Diagnostic Sciences, Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, Calif, USA
[e] Professor and Chair, Department of Orthodontics, Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, Calif, USA
Corresponding author: Dr. Heesoo Oh, Professor and Chair, Department of Orthodontics, University of the Pacific, Arthur A. Dugoni School of Dentistry, 155 Fifth Street, San Francisco, CA 94103
(e-mail: hoh@pacific.edu)

Accepted: October 2021. Submitted: May 2021.
Published Online: November 23, 2021

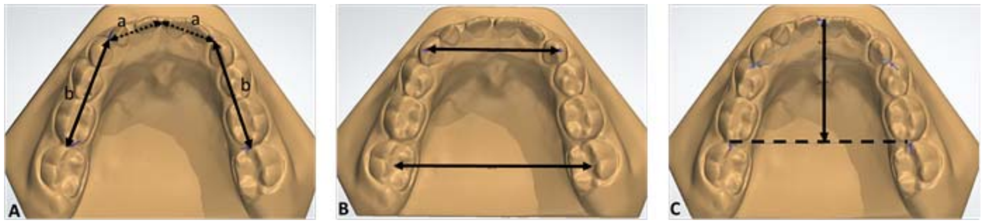

Figure 1. Measurements on the study casts. (A) Anterior and posterior perimeter. (B) Intercanine and intermolar width. (C) Arch depth.

studies were conducted during the course of 1 to 2 years during the transitional period from the late mixed to early permanent dentitions.

The purpose of this study was to investigate the long-term effects of an LLA on the lower dentition when it was placed from the early mixed dentition to the full permanent dentition until the eruption of the second molars. Specifically, the authors attempted to answer the following three questions: (1) What are the effects of the long-term use of an LLA on mesial and vertical movements of the lower incisors and molars? (2) What are the effects of the long-term use of an LLA on lower incisor inclination and molar angulation? (3) What are the effects of an LLA on arch dimension changes? Null hypotheses were tested by comparing patients with and without LLAs to answer these questions.

MATERIALS AND METHODS

This retrospective study on the LLA was part of a larger investigation of mixed dentition treatment that was conducted at the Craniofacial Research Instrumentation Laboratory, University of the Pacific School of Dentistry. This study was approved by the Institutional Review Board of the University of the Pacific (no. 16-104).

A full description of the original sampling strategy was reported elsewhere.[13] The main inclusion criteria were the availability of both lateral cephalometric radiographs and study casts at the following two time points: before phase 1 treatment in the early mixed dentition (T1) and at the end of LLA therapy (T2; evaluation for phase 2) in the permanent dentition after the mandibular second molars erupted. Of the 137 patients who had complete records, 98 patients received LLA treatment with or without treatment in the upper arch (LLA group), and 39 patients did not receive any treatment in the lower arch (no-LLA group).

LLA Treatment Protocol

The LLA group received phase 1 mixed dentition treatment that may have employed headgear and/or an upper "2 $\times$ 4" appliance. The LLA was used to preserve leeway space and resolve lower crowding. The LLA was fit passively to the lower permanent first molars to maintain the intermolar width. Often, the LLA was used in conjunction with selective extraction of the lower primary teeth. Typically, the LLA (0.030") was placed at the incisal third of the teeth to correct incisor crowding and rotations and was adjusted at each visit during the first 6 months until ideal incisor alignment was obtained. Once ideal lower incisor alignment was achieved, an LLA was placed passively above the cingulum of the lower incisors. After phase 1 treatment, the LLA was left in place until the lower second molars erupted, and records were taken to evaluate for phase 2 treatment.

The no-LLA group received treatment in the maxillary arch that typically included a 2 $\times$ 4 appliance and headgear or removable appliance, but no appliance was used in the mandibular arch.

Study Cast Analysis

Study casts were scanned using a three-dimensional model scanner and imported into the Ortho Analyzer 3D software (3Shape Inc, Copenhagen, Denmark). For each time point, arch width, arch perimeter, and arch depth were independently measured on the lower cast by two dentists (Figure 1). The average values of the two judges' estimates were used for all study cast measurements, and the changes between time points were calculated. The definitions of the measurements made on the study casts are shown in Table 1.

Lateral Cephalometric Analysis

Lateral cephalometric landmarks were digitized independently by two judges. Outliers were excluded based on the landmark-specific envelopes of error.[14] The average values were recorded in a numerical database, and cephalometric measurements were calculated by computer operations. Two orthodontic faculty members performed superimpositions. To evaluate sagittal and vertical changes for the incisors and molars, each patient's serial cephalometric tracings were superimposed using Bjork's structural superimposition method (Figure 2). An x/y coordinate system was established. The occlusal plane at T1 became the x axis, whereas the y axis was the line perpendicular to the x axis passing through the

Table 1. Definitions of Arch Dimension Measurements

Variable	Definition
Intercanine width	Distance between cusp tips
Intermolar width	Distance between the midpoint of the central fossa of the first molars
Arch depth	Perpendicular distance from the facial aspect of the central incisors at the midline embrasure to a line connecting the mesial surfaces of the permanent first molars
Anterior arch perimeter	The sum of distances from the mesial contact point of the central incisors to the mesial contact point of each canine
Posterior arch perimeter	The distance between the mesial contact point of each canine and the mesial contact point of the permanent first molar. At T1 (mixed dentition), it includes the C-D-E (the primary canine and first and second primary molars) and primate spaces; at T2 (permanent dentition), it includes the 3-4-5 space (permanent canine and first and second premolars) along with any additional spacing
Arch perimeter	The sum of the anterior and posterior arch perimeters
Modified leeway space	The sum of the widths of teeth 3-4-5 subtracted from the posterior arch perimeter at T1 (overestimated by existing interdental and primate spaces)
Anterior crowding	The sum of the widths of the lower incisors subtracted from the anterior arch perimeter at each time point

midpoint between the mesial buccal cusp tip (MBCusp) of the upper and lower first molars (L6) at T1. The intersection of the x and y axes was assigned as the origin. Changes in tooth position between T1 and T2 were measured relative to the occlusal plane (x axis). A positive sign in tooth position was assigned to superior and mesial movements from the origin. A negative sign was assigned to inferior and distal movements from the origin. To measure the sagittal position of the L6s, the x-coordinate values of the MBCusp and the mesial root apex (L6Apex) were used. Similarly, the x-coordinate values of the lower incisor edge (L1Edge) and the root apex (L1Apex) were used to determine the sagittal positions of the lower incisor. To assess the vertical effects of the LLA, the y-coordinate values for L6MBCusp, L6Apex, L1Edge, and L1Apex were used to determine vertical changes in the lower molars and incisors (Figure 2).

The lower incisor and molar angulations were computed relative to the occlusal plane (x axis; Figure 3). The long axis of L6, constructed by the L6MBCusp and the L6Apex, formed an angle with the occlusal plane. Similarly, the long axis of L1, constructed by L1Edge and L1Apex, formed an angle with the occlusal plane. The change in this angle between T1 and T2 was used to assess change in angulations of L6 and L1. Negative changes in angulation indicated distal tipping, and positive changes indicated mesial tipping movements.

Statistical Analysis

Interrater reliabilities for study cast measurements using intraclass correlation coefficients were excellent, ranging from 0.87 to 0.98. Descriptive statistics were generated to report the mean, standard deviation (SD), range, and proportions of demographic information for each group. Categorical variables such as sex and angle classification were evaluated using chi-square tests. Continuous variables from cephalometric and study cast measurements were compared between the LLA and no-LLA groups using unpaired *t*-tests. For variables in which significant differences existed between the LLA and no-LLA groups, multiple regression analysis was used to explain outcome variables

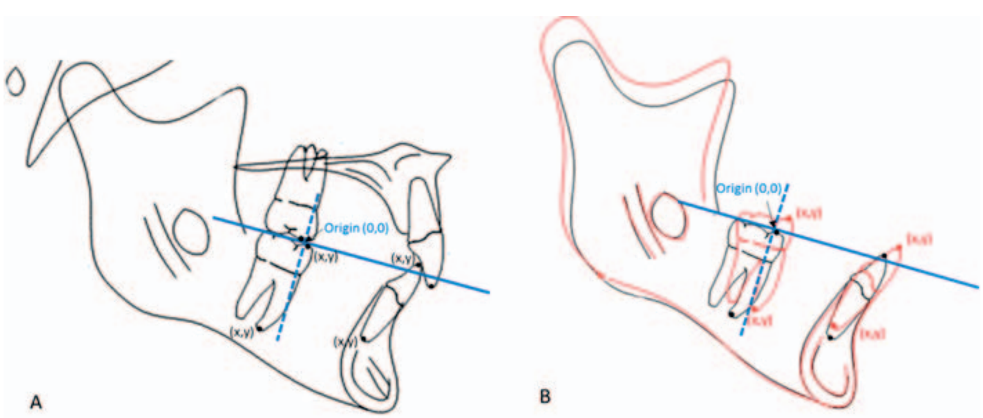

Figure 2. Measurements of the sagittal and vertical positions of the lower incisors, molar cusp tips, and root apices. Reference structures for mandibular superimposition were the anterior contour of the chin, the inner cortical plate of the symphysis, and the contour of the mandibular canal.

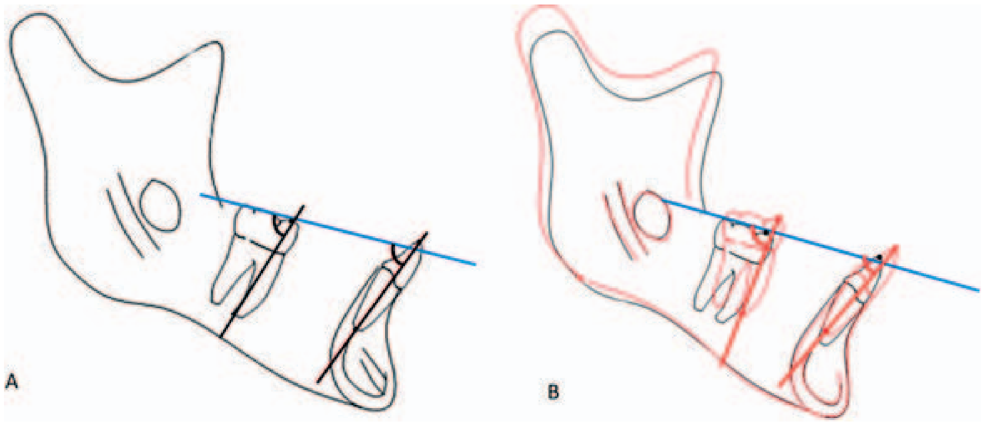

Figure 3. Measurements of the angulation of the lower incisor and molar to the occlusal plane.

based on the various independent variables. *P* values less than .05 were considered statistically significant. Statistical values were computed using SPSS software (version 25.0; IBM, Armonk, N.Y.).

RESULTS

The mean age at T1 was 8.5 ± 1.3 years for the LLA group and 8.3 ± 0.7 years for the no-LLA group. At T2, the mean age for the LLA group was 13.1 ± 1.3 years and 2.9 ± 0.98 years for the no-LLA group. There was no statistical difference in the T1 to T2 time interval between the LLA and no-LLA groups, which was 4.8 ± 1.6 years and 4.4 ± 1.0 years, respectively. There was no statistically significant difference in the proportion of sex and angle classification (Table 2).

Table 3 shows that the LLA and no-LLA group could not be distinguished from one another at T1 with respect to lower molar angulation, L6MBC sagittal position, L6Apex sagittal position, lower incisor angulation, and L1Apex sagittal position. The only difference at T1 was the L1Edge sagittal position; L1Edge was about 1.23 mm more distally positioned in the LLA group ($P = .003$). At T2, statistically significant differences were found in the lower incisor and molar angulations, L6Apex sagittal position, and L6MBC vertical position. Lower molars tended to tip mesially in the no-LLA group, but uprighted with an LLA; there was a difference of 7.87° ($P < .0001$). Interestingly, this L6 crown tip-back effect in the LLA group was attributed to changes in the sagittal position of the L6Apex (not by tipping of the crown distally), which moved more mesially in the LLA group (3.59 ± 2.59 mm) than in the no-LLA group (1.03 ± 3.3 mm; Figure 4). This difference between the two groups was highly significant ($P < .0001$).

The lower incisors proclined 6.06 ± 4.5° when an LLA was used compared with proclination of 1.83 ± 4.7° without an LLA. The proclination was corroborated by a statistically significant change in the sagittal position of the lower incisor incisal edge (forward 2.22 ± 2.2 mm with an LLA vs 0.41 ± 1.5 mm without). These findings suggested that treatment with an LLA had a tip-back effect on the lower molars and caused increased proclination of the lower incisors.

The vertical positions of the incisor at T1 and T2 were not statistically different between the LLA and no-LLA groups. In addition, the vertical positions of the lower molar apex at T1 and T2 were not statistically different between the two groups. The vertical position of the cusp, however, appeared to change from the same height at T1 to a statistically different level at T2; the changes in cusp height were 3.78 ± 2.4 mm with an LLA vs 2.61 ± 1.6 mm without an LLA.

Table 4 shows arch dimensional measurements from the study casts. Arch depth measured on the study cast showed significant differences between the group treated with an LLA and the group treated without an LLA at T1, T2, and change (T2–T1). From T1 to T2, the no-LLA group lost 2.2 ± 1.4 mm of arch depth, whereas the LLA group preserved arch depth,

Table 2. Sample Demographic Information of the LLA and no-LLA Groups

	LLA Group (n = 98)		no-LLA Group (n = 39)		Difference
	n	%	n	%	*P* Value[a]
Sex					
Male	41	41.8	14	35.9	NS[b]
Female	57	58.2	25	64.1	
Angle class					
Class I	8	8.2	5	12.8	NS
Class II	90	91.8	33	84.6	
Class III	0	0	1	2.6	

[a] Chi-square test.
[b] NS indicates not significant.

Table 3. Comparisons of Angular, Sagittal, and Vertical Changes in the Lower Incisor and Molar Positions Between the LLA and no-LLA Groups During the Study Period[a]

		LLA Group (n = 98)			no-LLA Group (n = 39)			Difference	
Measurement	Time Point	Mean	SD	*P* Value[b]	Mean	SD	*P* Value[b]	Mean	*P* Value[c]
Sagittal change									
L1 angulation (°)	T1	72.41	5.46		70.48	6.24		−1.92	NS[d]
	T2	66.38	5.08		68.66	5.56		2.27	.024
	T1–T2	6.06	4.49	<.0001	1.83	4.68	.02	4.23	<.0001
L1Edge (mm)	T1	28.83	2.13		30.06	2.2		1.23	.003
	T2	30.99	2.78		30.47	2.26		−0.52	NS
	T1–T2	2.22	2.21	<.0001	0.41	1.52	NS	−1.81	<.0001
L1Apex (mm)	T1	22.28	2.51		22.78	3.06		0.50	NS
	T2	21.3	2.62		22	2.81		0.70	NS
	T1–T2	−0.94	1.53	<.0001	−0.78	1.69	.006	0.16	NS
L6 angulation (°)	T1	77.17	5.34		78.71	4.04		1.50	NS
	T2	82.35	5.34		75.85	4.52		−6.49	<.0001
	T1–T2	−5.02	6.54	<.0001	2.86	5.56	.003	7.87	<.0001
L6MBCusp (mm)	T1	0.13	1.26		−0.12	1.46		−0.25	NS
	T2	2.71	1.99		2.03	2.31		−0.68	NS
	T1–T2	2.61	2.26	<.0001	2.15	2.44	<.0001	−0.46	NS
L6Apex (mm)	T1	−4.25	2.34		−4.13	2.08		0.12	NS
	T2	−0.65	2.58		−3.09	3.42		−2.44	<.0001
	T1–T2	3.59	2.59	<.0001	1.03	3.28	.06	−2.55	<.0001
Vertical change									
L1Edge (mm)	T1	0.44	2.08		−0.19	1.99		−0.63	NS
	T2	3.27	2.44		3.17	1.69		−0.10	NS
	T1–T2	2.87	2.33	<.0001	3.37	1.61	<.0001	0.49	NS
L1Apex (mm)	T1	−19.96	2.82		−20.1	3		−0.10	NS
	T2	−17.66	2.93		−18.48	3.12		−0.80	NS
	T1–T2	2.4	2.4	<.0001	1.59	1.9	<.0001	−0.84	.06
L6MBCusp (mm)	T1	−1.3	1.52		−1.3	1.5		0	NS
	T2	2.45	2.82		1.33	1.97		−1.12	.03
	T1–T2	3.78	2.42	<.0001	2.63	1.63	<.0001	−1.15	.007
L6Apex (mm)	T1	−20.41	2.16		−20.58	1.74		−0.17	NS
	T2	−18.92	3.09		−19.16	2.83		−0.25	NS
	T1–T2	1.53	2.61	<.0001	1.41	2.34	5E-04	−0.12	NS

[a] All measurements were made from the mandibular structural superimposition (Figures 4 and 5).
[b] Probability of change between T1 and T2.
[c] Probability of difference between the LLA and no-LLA groups.
[d] NS indicates not significant.

and the change was not statistically significant (loss of 0.34 mm).

The LLA group showed an arch width increase of about 1 mm more than the no-LLA group at both the canines and the molars. Arch perimeter was statistically different between the two groups at T1 but was similar for the LLA and no-LLA groups at T2. Change in arch perimeter was significantly different. The group treated without an LLA lost 3.62 ± 2.6 mm of arch perimeter from T1 to T2, whereas the group treated with an LLA lost 0.97 ± 3.7 mm. Thus, with an LLA, there was about 2.6 mm "savings" of arch perimeter.

Multiple regression analysis for predicting arch perimeter changes revealed that an LLA mediated a significant change in arch perimeter primarily through leeway space, but also through incisor proclination and increased intercanine width. The model accounted for 88% of the variance in arch perimeter changes ($P <$ .0001).

DISCUSSION

Beyond leeway space, the most significant contributions to the interaction between the arch perimeter and the LLA are lower incisor proclination and changes in intercanine and intermolar widths. In theory, the amount of crowding resolved should be dependent on the interaction between crowding at T1, the amount of leeway space, and changes in arch perimeter mediated by the LLA. Change in arch perimeter could be affected by change in arch width or change in arch depth. Arch depth could be affected by angular and sagittal changes in both the lower incisor and lower molar (Figure 5).

This study confirmed that the interaction between leeway space and the LLA was the primary factor affecting arch depth and perimeter, which was consistent with previous literature.[4–8] Rebellato et al.,[7] Singer,[8] and Brennan and Gianelly[4] all showed minimal

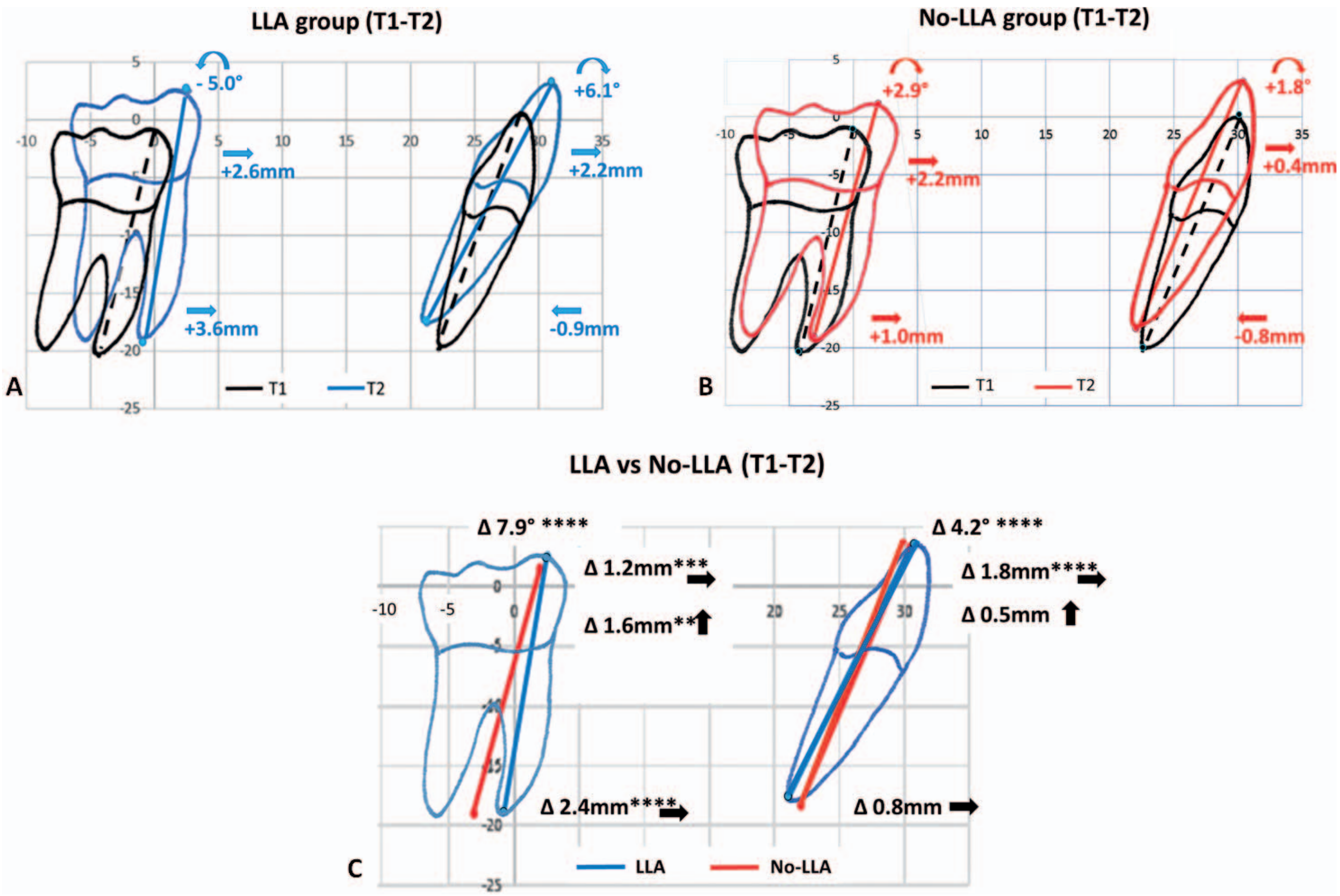

Figure 4. Lower incisor and molar movement relative to the initial tooth position on the mandibular superimposition in both the (A) LLA and (B) no-LLA groups. Positive changes indicate mesial movement and mesial tipping, and negative changes indicate distal movement and distal tipping. (C) Comparison of the angulations and sagittal and vertical changes of the molars and incisors between the two groups at T2. Δ indicates difference between two groups; → indicates mesial movement; ↑ indicates vertical movement. *$P < .05$; **$P < .01$; ***$P < .001$; ****$P < .0001$.

Table 4. Comparison of Study Cast Measurements Between the LLA and no-LLA Groups at T1, T2, and Changes (T1–T2)

Measurement	Time Point	LLA Group (n = 98)			no-LLA Group (n = 39)			Difference	
		Mean	SD	P Value[a]	Mean	SD	P Value[a]	Mean	P Value[b]
Arch depth (mm)	T1	24.1	1.9		25.1	1.7		−1.0	.004
	T2	23.7	1.7		22.8	1.8		0.9	.007
	T1–T2	−0.34	1.9	NS[c]	−2.2	1.4	<.0001	1.9	<.0001
Arch width L3–3 (mm)	T1	24.8	2.2		25.9	2.0		−1.2	.005
	T2	26.2	2.0		26.4	1.9		−0.2	NS
	T1–T2	1.4	2.0	<.0001	0.4	1.8	NS	0.9	.01
Arch width L6–6 (mm)	T1	40.3	2.2		41.1	1.7		0.8	.03
	T2	42.2	2.0		42.0	1.8		0.2	NS
	T1–T2	1.9	1.8	<.0001	0.9	1.4	.0005	1.0	.003
Arch perimeter (mm)	T1	67.5	3.7		69.4	3.1		−1.8	.007
	T2	66.6	3.5		65.8	3.6		0.7	NS
	T1–T2	−0.97	3.7	.01	−3.6	2.6	<.0001	2.6	.0001
Anterior crowding (mm)	T1	−1.8	1.9		0.2	2.1		1.9	<.0001
	T2	−0.02	1.0		0.1	1.2		0.1	NS
	T1–T2	1.78	2.0	<.0001	−0.1	1.8	NS	1.9	<.0001
Leeway space (mm)		4.8	3.6		6.01	2.2		1.3	.04

[a] Probability of change between T1 and T2.
[b] Probability of difference between the LLA and no-LLA groups.
[c] NS indicates not significant.

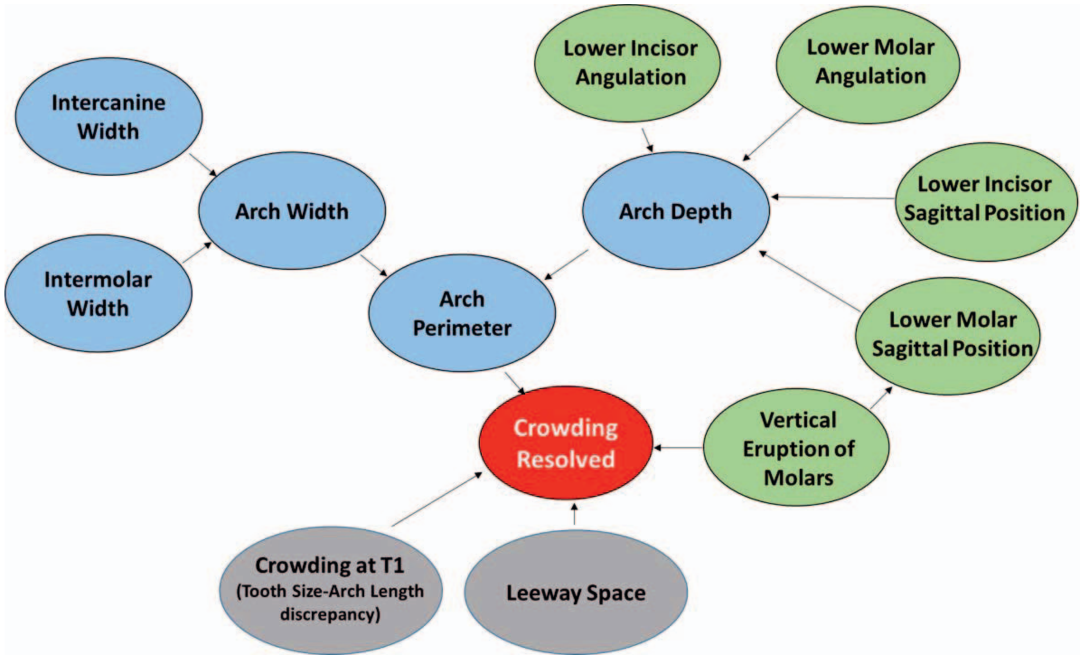

Figure 5. Various contributing factors for resolving anterior crowding. Gray indicates patient host factors, blue indicates arch dimensional changes collected from the study casts, and green indicates sagittal and vertical position changes of the lower incisors and molars obtained from the lateral cephalometric radiographs.

changes in arch depth with an LLA. In addition, consistent with previous reports,[6,7,9] incisor proclination was a significant change caused by the LLA. The present study showed about 4° greater lower incisor proclination with the long-term use of a passive LLA. This finding suggests that the LLA effectively preserved arch perimeter at the expense of lower incisor proclination, which may or may not be a desirable effect depending on the facial growth pattern. For instance, in a hypodivergent growing patient having forward rotation of the mandible, a passive LLA is a simple and effective tool to facilitate favorable dentoalveolar compensation by preventing lingual tipping of the lower incisors. However, in a hyperdivergent growing patient, an LLA prevents vertical and lingual eruption of the lower incisors to compensate for the vertical direction of mandibular growth.

In contrast, Villalobos et al. did not report lower incisor proclination. Instead, they proposed that the LLA prevented normal incisor uprighting. This discrepancy may be attributed to a sample selection that included only normo- and hypo-divergent facial types.[10]

Molar tip-back attributed to LLA therapy has also been previously reported.[7,8,10] Rebellato et al.[7] and Villalobos et al.[10] found similar molar angulation changes, with the molars being tipped back approximately 0.5° with an LLA as opposed to approximately 2.1° of mesial tipping in the control group. In those studies, the observation periods were relatively short. With a much longer observation period, the current study showed a greater molar angulation change of 5°. However, the sagittal position of the L6Cusp was similar. Comparable magnitudes of mesial movement in the lower molars were observed in both groups (Figure 4).

Restricting vertical eruption of the lower molars would be most beneficial in the treatment of high-angle patients. Thus far, the literature was divided on vertical effects of an LLA. Villalobos et al.[10] demonstrated that the LLA could limit eruption of the lower molars by 0.29 mm over 18 months. Singer[8] also showed vertical control with the lingual arch (0.6-mm eruption with LLA vs 1-mm eruption in control). On the other hand, Rebellato et al.[7] and Odom[11] both showed no vertical effects of the LLA in preventing the eruption of teeth. In the present study, the only significant finding with respect to vertical changes was the increased vertical position of the mesial buccal cusp tip of the lower molar with an LLA. These findings suggest that the LLA did not limit vertical eruption of molars. One explanation for the increased vertical position of the mesial buccal cusp tip is the tip-back effect of the LLA, which would cause the MB cusp tip to rise above the occlusal plane. Further supporting evidence is that the vertical changes associated with the mesial root apex were not significantly different between the LLA and no-LLA groups. The sagittal change was greater (more mesial movement of the root apex) in the LLA group than in the no-LLA group. From previous short-term studies[7,8,10] and the present long-term study, it can be inferred that, although an LLA may cause distal tipping of the lower molars initially, it does not seem to restrict the superior and mesial movements of the lower dentition in the long term. In fact, molar angulation change was attributed to more mesial movement of the mesial root of L6 (L6Apex) in the LLA group than in the no-LLA group.

Previous literature has reported a slightly higher chance of mesial impaction or inhibited eruption of the second molars in the presence of an LLA, lip bumper, and Schwartz appliance. Further study is needed to determine whether the early tip-back effect adversely impacts second molar eruption.

The finding that the LLA had widening effects of about 1 mm at both the canines and molars was consistent with previous studies.[4,6–8] However, the mechanisms of this increase have not been fully investigated. It is possible that the increase in intermolar width is a function of buccal-lingual uprighting of the molars. The change in torque is thus measured as an increase in width because the width is measured from the occlusal surface. This is an area for future research.

Overall, it seems that the effects of long-term use of an LLA from the early mixed dentition were similar to those reported for short-time use in preserving leeway space for about 1 to 2 years. However, an additional benefit of the long-term use of an LLA is achieving and maintaining nearly ideal alignment of the lower incisors with selective extraction of the primary teeth without any additional appliances.[6,13] In a previous study, about one-third of patients who were treated with this approach did not receive further treatment in the permanent dentition.[13]

As with any retrospective study, there were some limitations that should be noted. The two groups of patients (those who received LLA treatment and those who did not) were not intrinsically the same at the beginning of treatment. In addition, because the study lacked an untreated control group, any effects from treatment in the maxillary arch cannot be ruled out, and further research is necessary. However, despite these limitations, this study still provides useful information on the long-term effects of LLA treatment on the lower incisors and molars during a period of 4.5 years from the early mixed dentition to the full permanent dentition.

CONCLUSIONS

- The LLA does not restrict mesial movement or vertical eruption of the lower molars and incisors.
- A molar tip-back effect and lower incisor proclination resulted from the LLA. The lower molar angulation change was attributed to more mesial movement of the L6 mesial root.
- Treatment with an LLA prevents loss in the arch perimeter that normally occurs during the transition from the mixed to permanent dentition via preservation of leeway space, incisor proclination, and widening at the canines.

REFERENCES

1. Moyers RE. *Handbook of Orthodontics*. 4th ed. Ann Arbor, MI: Year Book Medical Publishers Inc; 1988:127–140.
2. Sinclair P, Little R. Maturation of untreated normal occlusions. *Am J Orthod Dentofacial Orthop*. 1983:83;114–123.
3. Sillman JH. Dimensional changes of the dental arches: a longitudinal study from birth to 25 years. *Am J Orthod*. 1964; 50:824–841.
4. Brennan MM, Gianelly AA. The use of the lingual arch in the mixed dentition to resolve incisor crowding. *Am J Orthod Dentofacial Orthop*. 2000;117:81–85.
5. DeBaets J, Chiarini M. The pseudo Class I: a newly defined type of malocclusion. *J Clin Orthod*. 1995;29:73–88.
6. Dugoni SA, Lee JA, Varela J, Dugoni AA. Early mixed dentition treatment: postretention evaluation of stability and relapse. *Angle Orthod*. 1995;65:311–320.
7. Rebellato J, Lindauer SJ, Rubenstein LK, Isaacson RJ, Davidovitch M, Vroom K. Lower arch perimeter preservation using the lingual arch. *Am J Orthod Dentofacial Orthop*. 1997;112:449–456.
8. Singer J. The effect of the passive lingual archwire on the lower denture. *Angle Orthod*. 1974;44:146–155.
9. Owais AI, Rousan ME, Badran SA, Abu Alhaija ES. Effectiveness of a lower lingual arch as a space holding device. *Euro J Orthod*. 2011;33:37–42.
10. Villalobos FJ, Sinha PK, Nanda RS. Longitudinal assessment of vertical and sagittal control in the mandibular arch by the mandibular fixed lingual arch. *Am J Orthod Dentofacial Orthop*. 2000;118:366–370.
11. Odom WM. Mixed dentition treatment with cervical traction and lower lingual arch. *Angle Orthod*. 1983;53:329–342.
12. Viglianisi A. Effects of lingual arch used as space maintainer on mandibular arch dimension: a systematic review. *Am J Orthod Dentofacial Orthop*. 2010;138:382.e1–382.e4.
13. Oh H, Baumrind S, Korn E, et al. A retrospective study of Class II mixed-dentition treatment. *Angle Orthod*. 2017;87: 56–67.
14. Baumrind S, Miller D. Computer-aided head film analysis: the University of California San Francisco method. *Am J Orthod*. 1980;78:41–65.